Asynchronous Dictionary Learning for Remote Sensing Imagery Classification

Kirtus Leyba[1,3,4] and Prerna Patil[1,2]

Ming Yan[5], Emily Schultz[1], and Youzuo Lin[1]

[1]Los Alamos National Laboratory [2]Brown University [3]University of New Mexico [4]Arizona State University [5]Michigan State University

Introduction

Machine learning is an active area of research in the science and engineering domains. Among its many applications, machine learning has been used to classify hyperspectral imaging data. Large datasets and high computational complexity serve as barriers that limit the practical use of machine learning algorithms. As a potential technique to sidestep these barriers we took the novel approach of applying an asynchronous machine learning algorithm. We also evaluated the capability for such algorithms to be parallelized and refitted for high-performance computing resources.

Algorithms

In order to generate a classification of our hyper-spectral imaging data, we needed to solve the following sparse coding problem:

$$\underset{\alpha}{\mathrm{argmin}}, \text{ subject to } ||D\alpha - x||_2 \leq \epsilon$$

Where α represents a coefficient vector, D is a dictionary of atoms, and x is a signal from the data. Once this **objective function** is minimized, the resulting coefficient vector can be used to determine a classification of the data signal x.
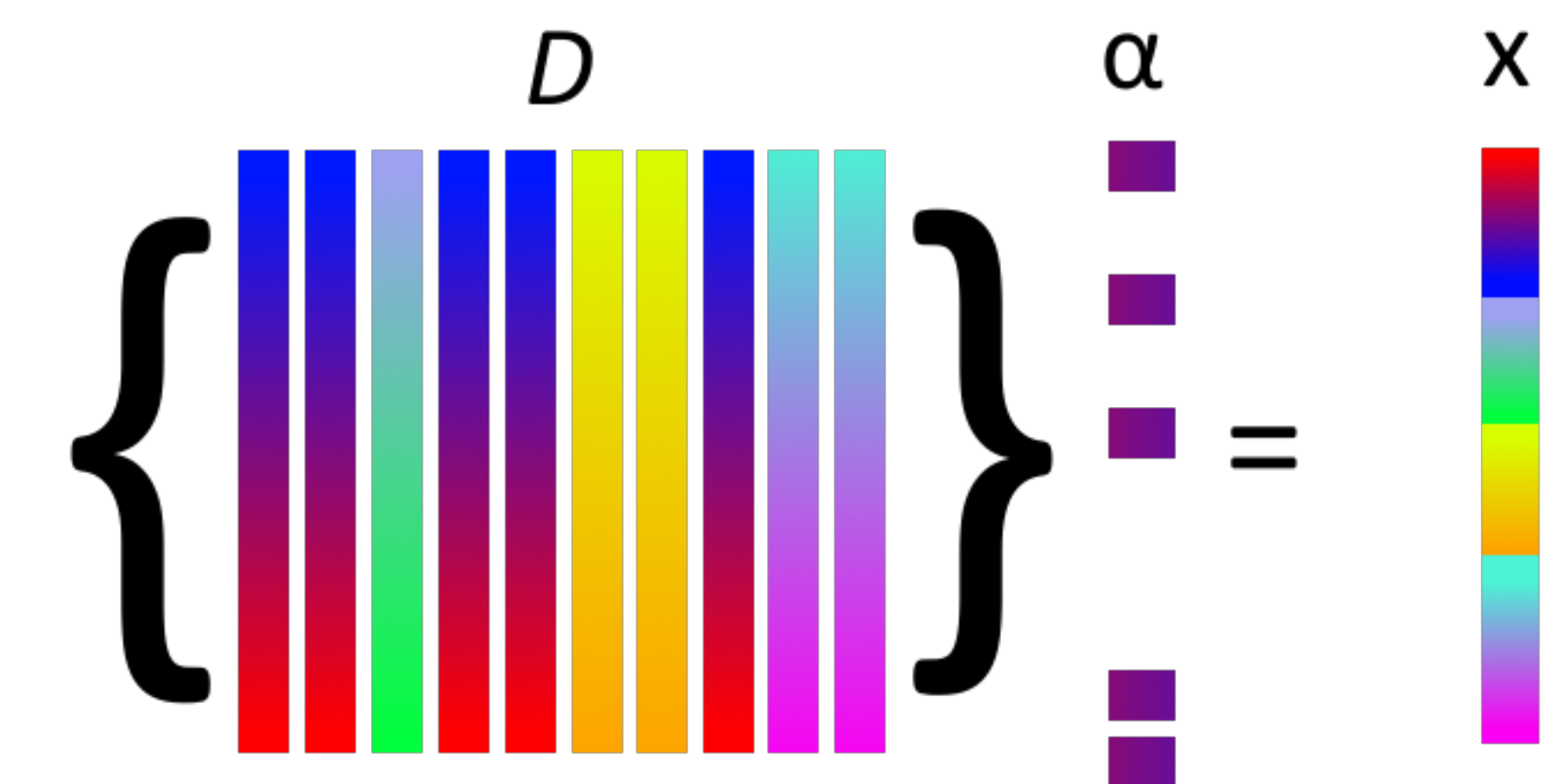

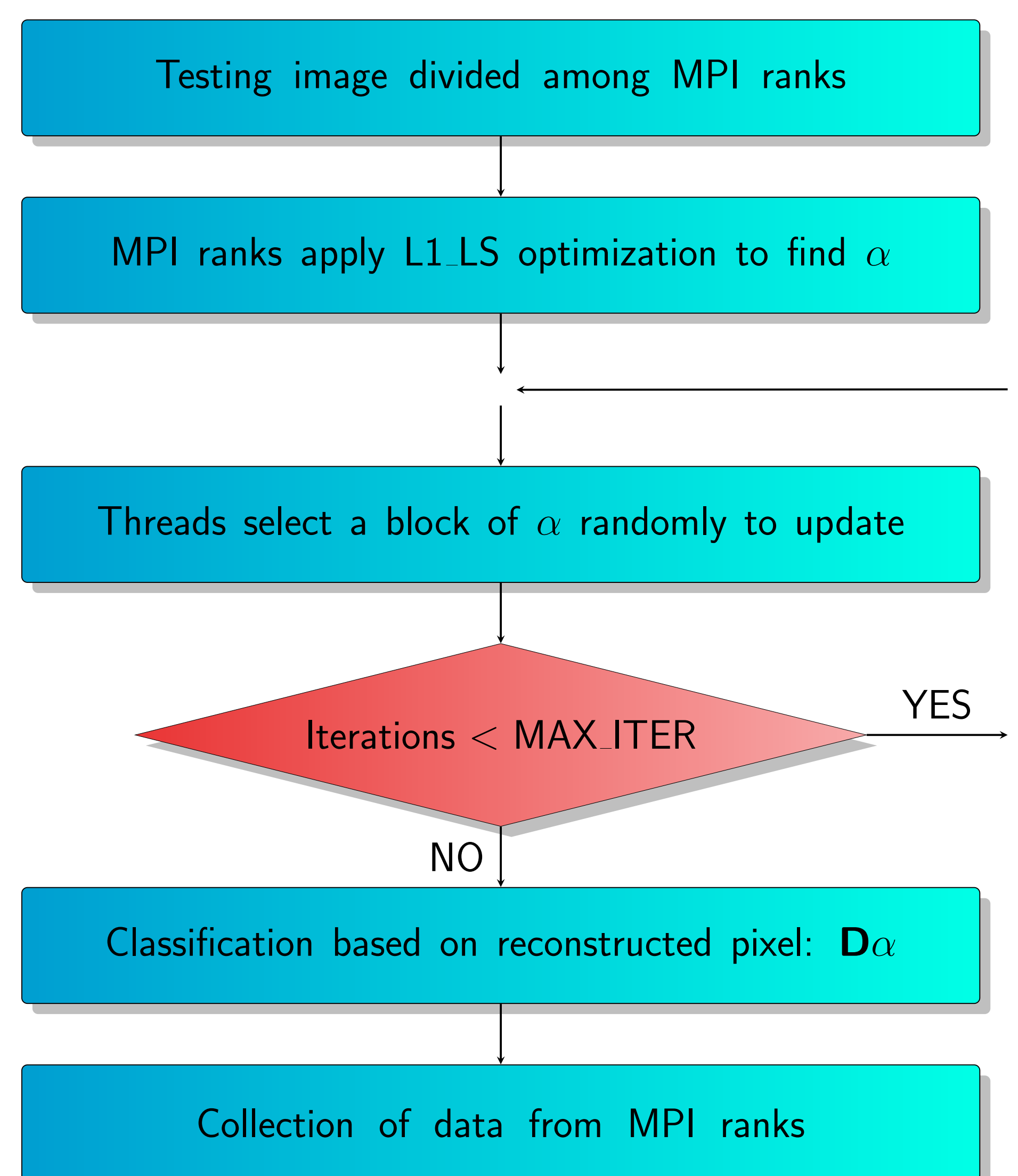Figure 1: Visual representation of the sparse coding dictionary learning problem

Figure 2: ARock algorithm
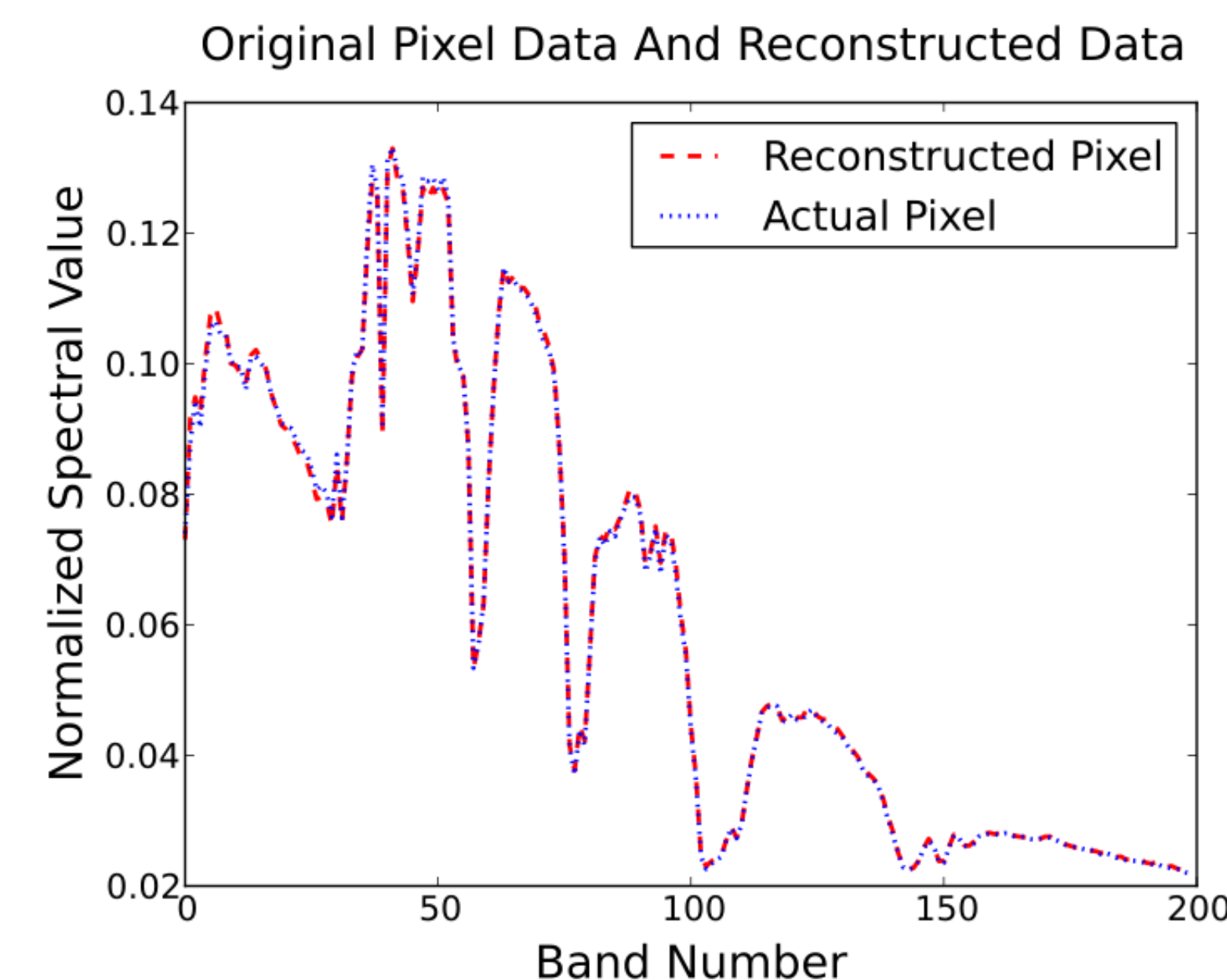
Reconstruction

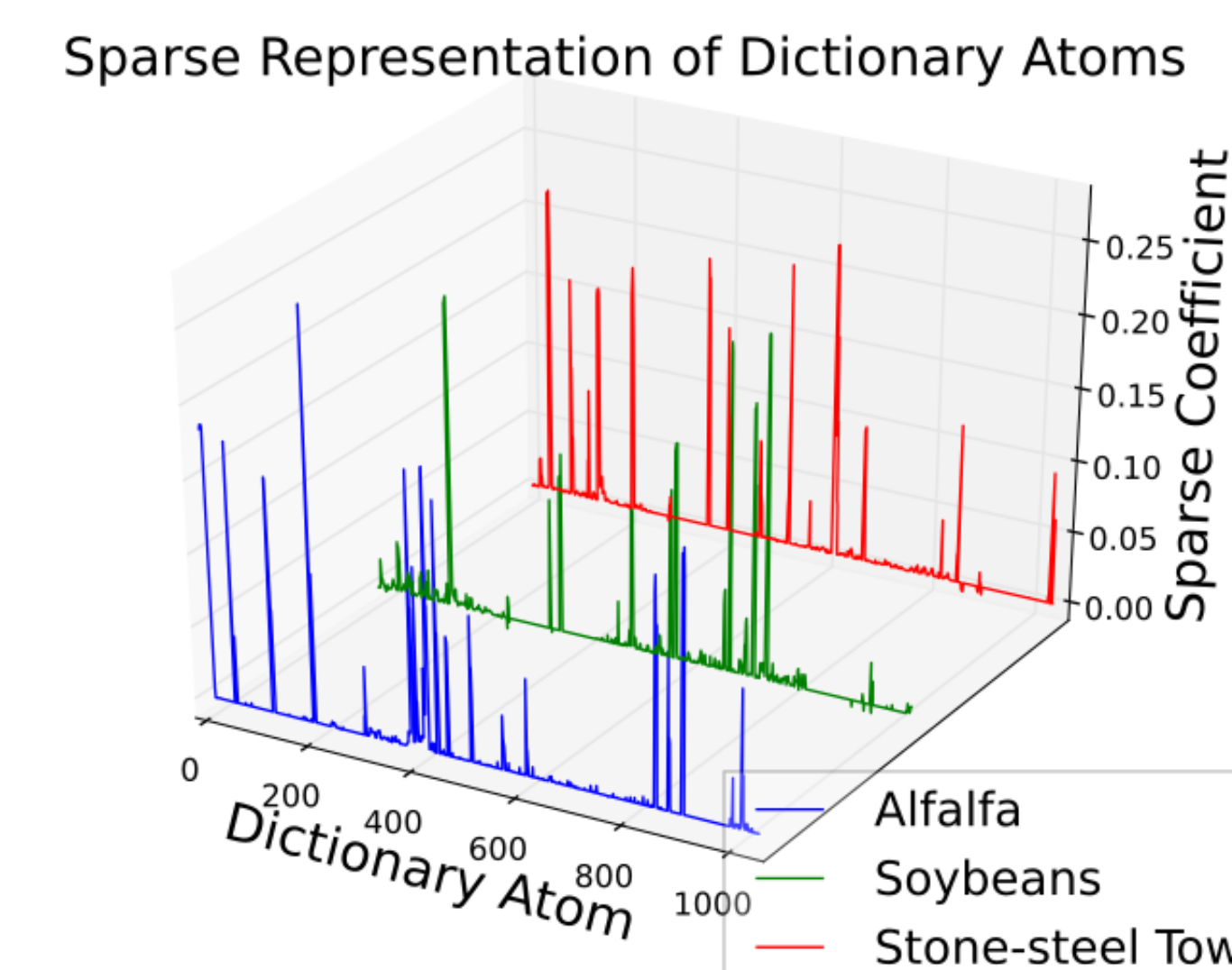

Figure 3: Pixel reconstruction for ARock

Figure 4: Sparse representation of pixel data generated by ARock
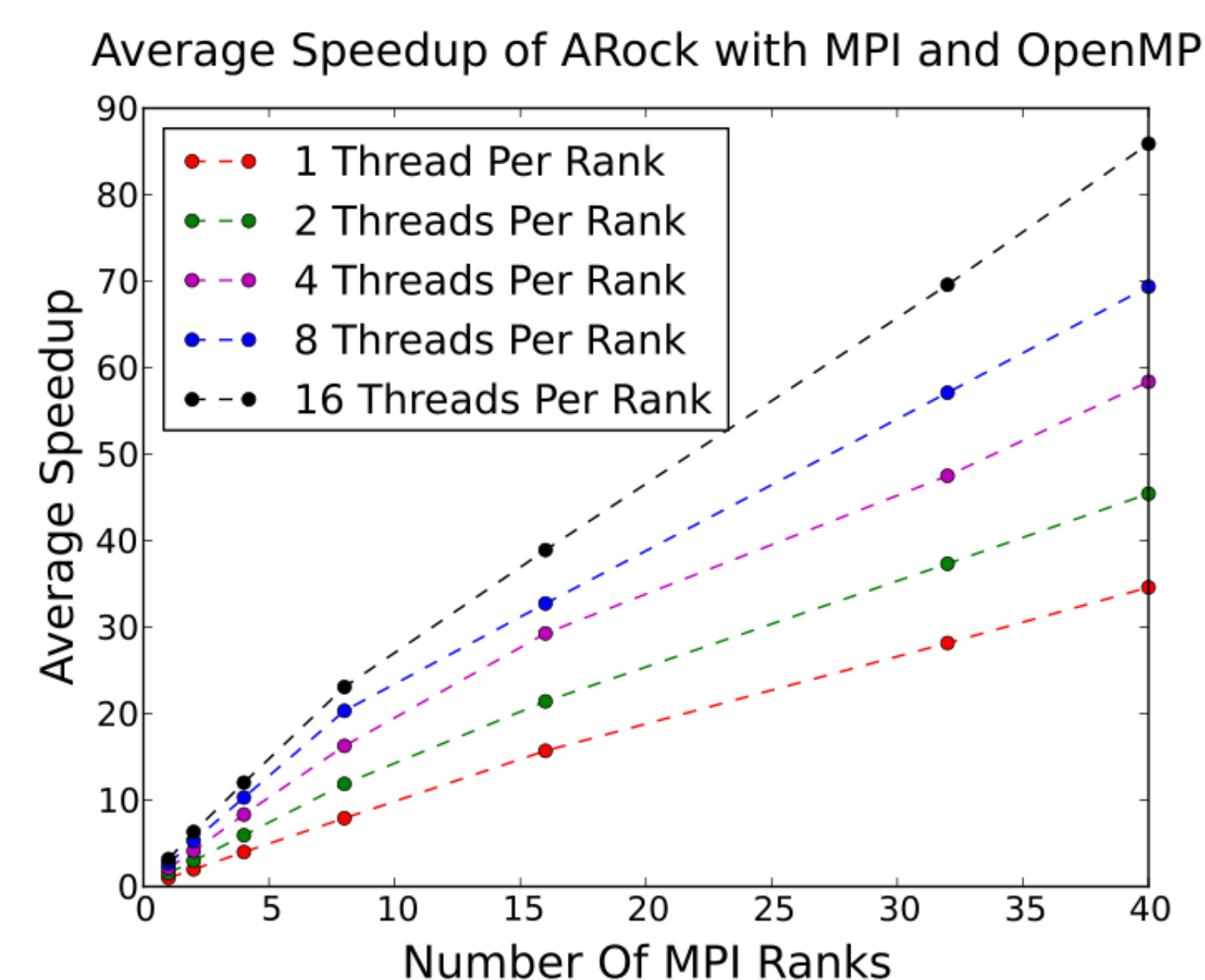
Performance

Figure 5: Speedup of ARock as a function of MPI ranks and OpenMP threads. All tests were carried out with round robin node distribution on 10 Intel E5-2695v4 Broadwells with hyperthreading
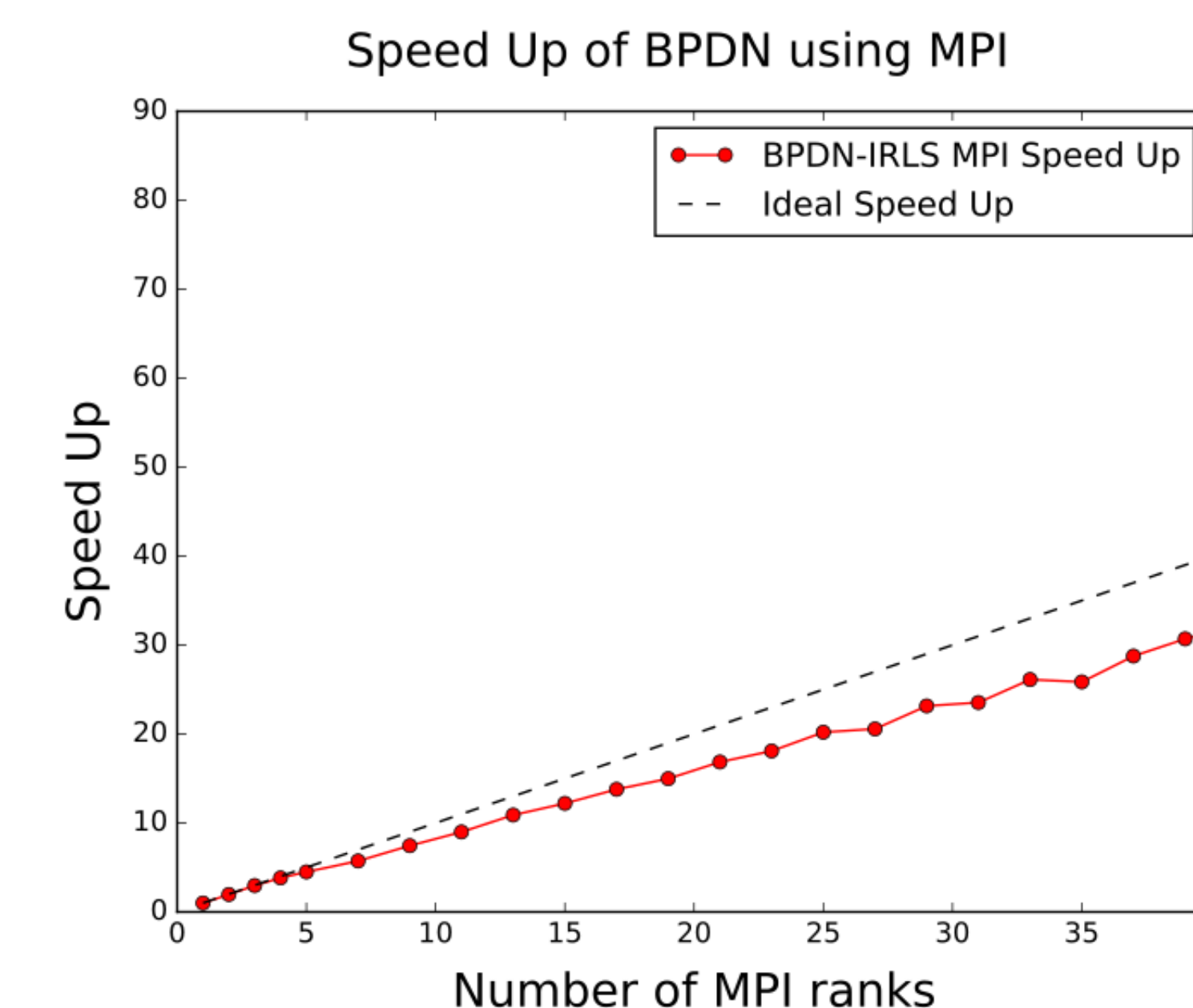

Figure 6: Speedup of baseline BPDN algorithm across multiple MPI ranks. All tests were carried out with round robin node distribution on 10 Intel E5-2695v4 Broadwells with CTS-1 scalable architecture
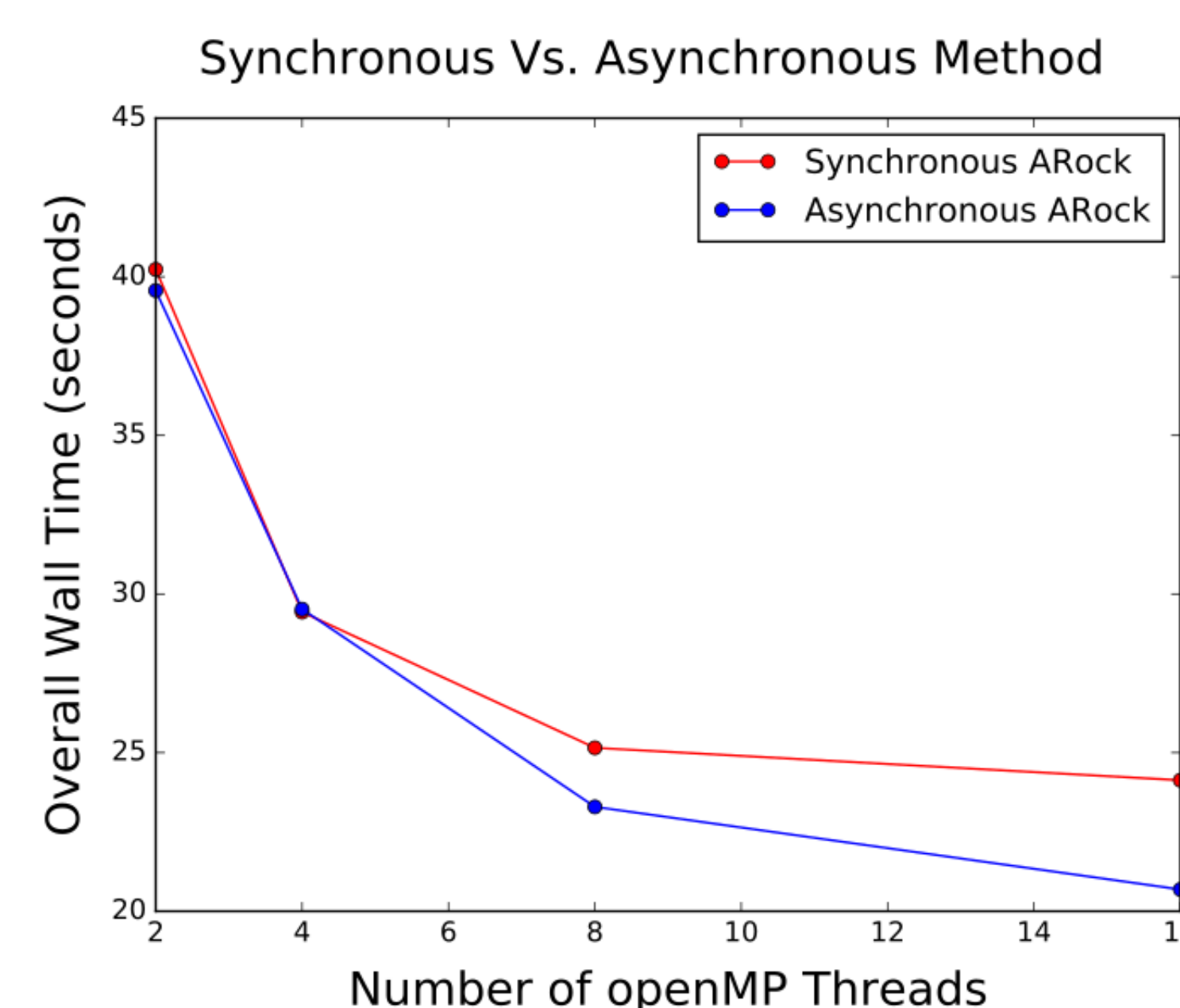
Asynchronous Methods

Figure 7: The performance gain from utilizing asynchronous techniques in the ARock algorithm
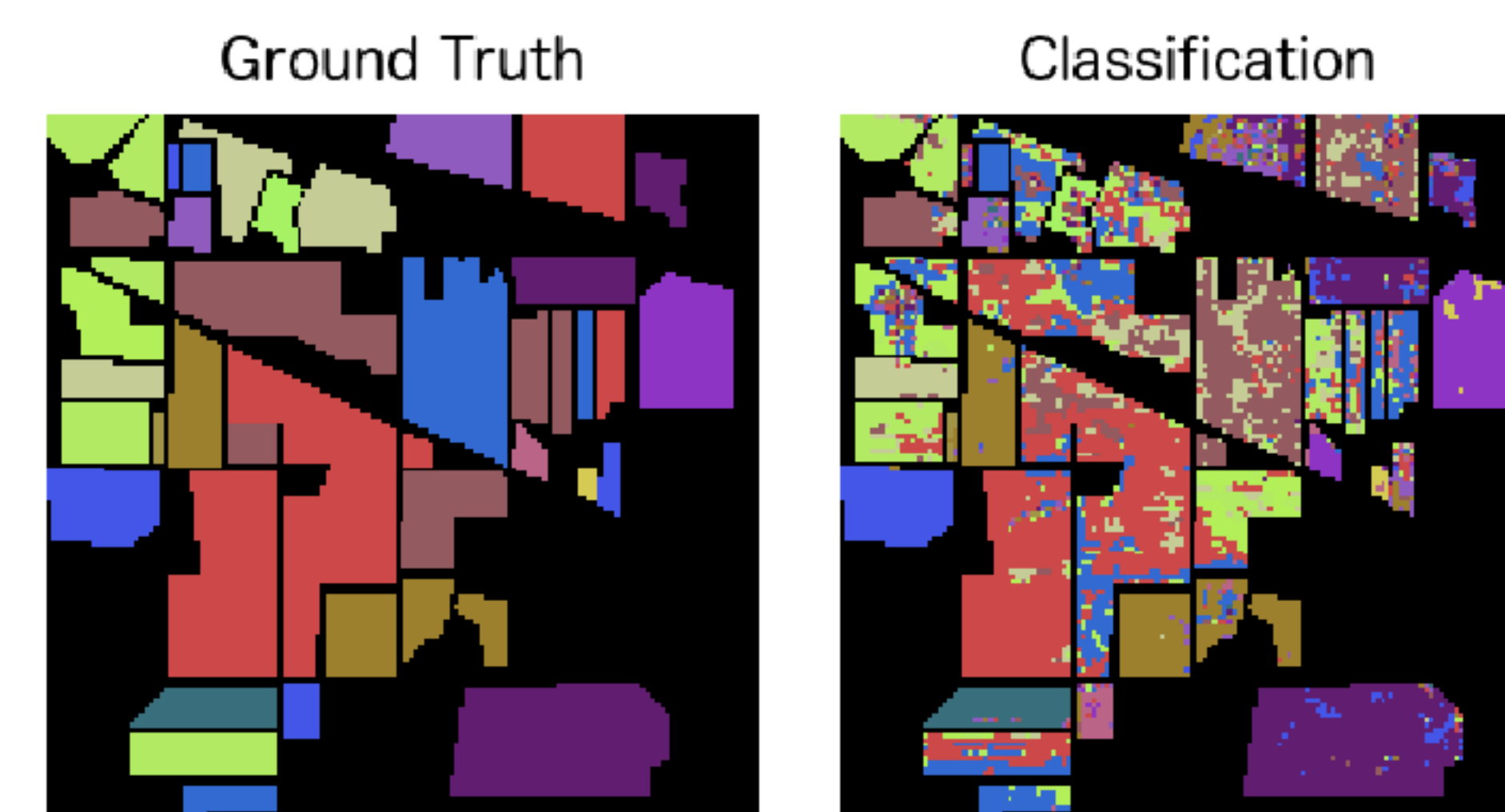
Classification

Figure 8: The ground truth and classification of the hyperspectral imaging data

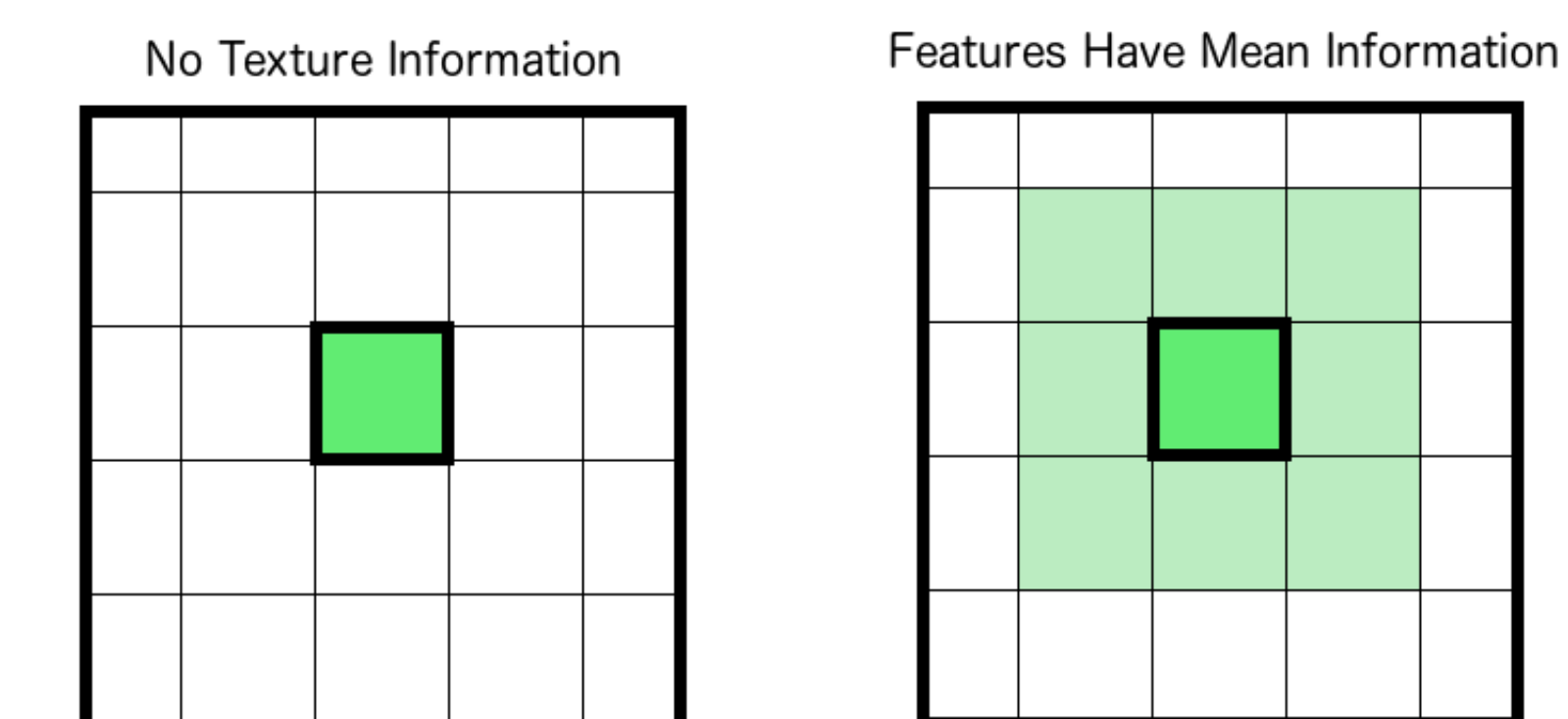## Future Work: Spatial Information

Figure 9: Current research in classification algorithms suggest that including the texture or spatial information (such as the mean and standard deviation across neighboring pixels) will result in a more accurate classification. Future work entails implementing such spatial consideration into the asynchronous ARock technique.

Conclusions

We have shown that the practices of parallelism in high-performance computing are readily applicable to machine learning algorithms. Sparse dictionary learning problems feature easily divisible problem domains, that yield well to parallel techniques on multiple scales. Our efforts were successful in simultaneously dividing large problems into chunks that can be worked synchronously, as well as dividing individual subproblems into problems that can be solved asynchronously with minimal communication. We have also demonstrated that the ARock asynchronous algorithm set provides a fast and reliable method for classifying hyper-spectral imaging data.

References

[1] Yi Chen and Nasser M. Nasrabadi.
Hyperspectral image classification using dictionary-based sparse representation.
IEEE Transactions On Geoscience and Remote Sensing, 49(10), 2011.

[2] Zhimin Peng, Yangyang Xu, Ming Yan, and Wotao Yin.
Arock: An algorithmic framework for asynchronous parallel coordinate updates.
Society for Industrial and Applied Mathematics, 38(5), 2016.

Acknowledgements

LA-UR-17-26765